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A STUDY OF CRYOGENIC TECHNIQUES FOR OPERATING HYDROGEN MASERS.(U)
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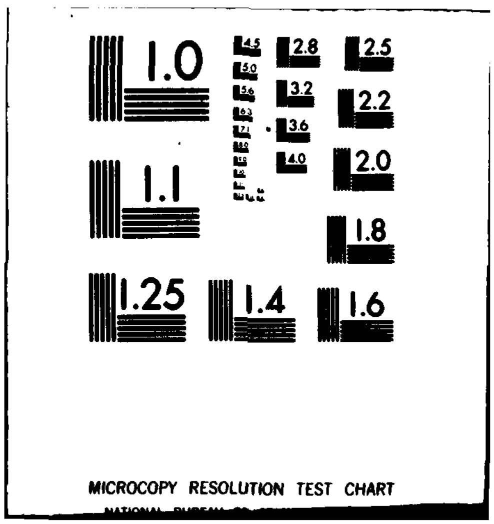
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LEVEL II

A STUDY OF CRYOGENIC TECHNIQUES FOR OPERATING HYDROGEN MASERS.

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Interim Report.
For the period from 1 July 1979 ~~to~~ 31 January 1980

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Atomic Hydrogen Maser Oscillator - Frequency Standard -
Cryogenic Cooling - Superconducting Magnetic Shields -
Low Noise Electronics

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Cryogenic Techniques are applied to the Atomic Hydrogen Maser Frequency Standard to extend the storage time of the atoms and reduce the thermal noise accompanying the signal and within the resonance linewidth. Oscillation has been achieved below 25K using wall coatings of frozen CF_4. A pair of new masers is under construction so that frequency stability improvement can be measured. Stability at the 1 x 10- level in $\Delta f/f$ for averaging time intervals of 1,000 seconds is expected at temperatures below 30K.

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A STUDY OF CRYOGENIC TECHNIQUES FOR OPERATING HYDROGEN MASERS

ONR CONTRACT NO. N00014-77-C-0777

Principal Investigator: R.F.C. Vessot

CONTRACT DESCRIPTION:

This experimental study involves the operation of hydrogen masers at low temperatures to obtain measurements of the wall collision relaxation of atomic hydrogen hyperfine structure on various types of surfaces. Our goal is to extend the operating temperature of the hydrogen well below the present normal operating temperature of $50^{\circ}C$. Low temperatures offer many attractive possibilities for improving upon the presently available stability $\frac{\Delta f}{f} \sim 6 \times 10^{-16}$ at 1,000 seconds.

1. Thermal noise is reduced.
2. Atomic velocity is reduced providing:
   a) Longer mean free time between collisions with the storage container wall--lower collision rate.
   b) Longer storage time.
   c) Much smaller electronic spin exchange cross section allowing higher density of atoms in the bulb and consequently higher power output.
3. Use of cryogenic techniques of superconductivity for cavity and magnetic shielding.

The approach we have taken is to use a 15 cm dia. x 18 cm long TE_{111} mode r.f. cavity (instead of the usual 28 cm dia. x 28 cm long TE_{110} mode cavity) placed in a non-magnetic vacuum cryostat surrounded by magnetic shields. Using high vacuum molecular beam methods, a collimated beam of atomic hydrogen is state selected by a hexapole magnet and directed into the maser storage volume through its collimator. The maser is made to oscillate and atomic resonance linewidth and frequency measurements are made as a function of temperature as the cavity temperature is decreased. From this we can calculate the real and imaginary parts of the wall relaxation probability for atomic hydrogen on wall surfaces of various types.

Using surfaces coated with Teflon FEP 120 (Fluorinated Ethylene Propylene Co-polymer) we can operate successfully as low as 50K before substantial wall quenching occurs. An important improvement we have made is that we have found that by freezing a coating of Carbon Tetrafluoride (CF_4) onto the storage volume surfaces, successful oscillation can be obtained as low as 25K.

Under these conditions we calculate that frequency stability of $\frac{\Delta f}{f} \approx 1 \times 10^{-16}$, or lower, should be available. With the existing apparatus we will test the behavior at lower temperature since, as yet, there appear to be no fundamental problems for operating at colder temperatures. A more efficient way of coating the cavity interior with CF_4 will also be tested.

We are presently engaged in a complete redesign of the system for making stability measurements under controlled conditions in addition to measuring the wall relaxation and wall shift. A parallel effort is underway using computer assisted techniques for parameterizing the behavior of the maser from first principles so as to unravel the many interacting variables related to temperature such as velocity, spin exchange cross section, and the real and imaginary parts of the hydrogen wall collision phase decorrelation process.

We have published the following:

1979 Research with a Cold Atomic Hydrogen Maser
R.F.C. Vessot, E,M, Mattison and E.L. Blomberg
Proc. 23rd Annual Symposium on Frequency Control,
Atlantic City, N.J., May 30 - June 1, 1979.

1979 Design, Construction and Testing of a Small Passive Hydrogen Maser
E.M. Mattison, G.U. Nystrom and R.F.C. Vessot
Proc. 23rd Annual Symposium on Frequency Control,
Atlantic City, N.J., May 30 - June 1, 1979.

1979 Hydrogen Maser Frequency Standards - R.F.C. Vessot
Radio Inteferometry Techniques for Geodesy
Mass. Institute of Technology, June 19-21, 1979. To appear in proceedings.

1979 Clocks and Relativity Experiments - R.F.C. Vessot

Invited paper at the Second Marcel Grossman Meeting on the Recent Developments of General Relativity at the International Center for Theoretical Physics

Trieste, Italy, July 5-11, 1979. To appear in proceedings.

We do not expect to have any unspent funds at the end of the contract period. We have no graduate students at work on this program. Parallel support for cold maser research is on hand for this fiscal year (1980) from the following sources.

Smithsonian Institution - $35K

Jet Propulsion Laboratory - $51K (Contract No. 955633)

Other support for maser programs for engineering and fabrication of deliverable maser items is as follows:

NRL:	Contract No. N00014-79-C-0718 Passive Masers for GPS Program	($275.K)
NASA - JPL:	Contract No. 954938 VLG-11 Hydrogen Maser for field use	($312.K)
NASA-MSFC :	Contract No. NAS8-33521 Test program for atomic hydrogen dissociators suitable for long-term operation in spacecraft.	($27.K)